WOOD PRODUCTION AND CONVERSION IN EASTERN ONTARIO

PHASE II

Preliminary Technical and Economic Assessment

Report prepared for the
ONTARIO MINISTRY OF ENERGY

Ministry of Energy Ontario

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Report prepared for the
ONTARIO MINISTRY OF ENERGY
by
Peat, Marwick and Partners
Management Consultants
Toronto, Ontario
August 1981

ABSTRACT

WOOD PRODUCTION AND CONVERSION IN EASTERN ONTARIO

PHASE II

Peat, Marwick and Partners were retained by the Ontario Ministry of Energy to investigate the technical and economic feasibility of converting wood into energy in Eastern Ontario. The objectives of Phase II of the study were to provide an engineering design and preliminary cost analysis of:

- a 10-MW electricity generating station at Perth or Carleton Place
- a 9-MW steam and electricity facility at Edwardsburgh;
- a 60 ton per day methanol plant to be located at Perth, Carleton Place or Edwardsburgh.

The report also considers the development of a fuel wood supply system to meet local markets.

Estimates were provided for wood requirements for each proposed plant as well as for a fuel wood market. Costs were compared for the development of wood harvesting, wood transportation, and plant material handling systems for each facility.

An engineering analysis at the pre-feasibility level was conducted for each plant. Included in the analysis were process flow diagrams plant layout diagrams, schematic diagrams of major capital equipment, lists of capital equipment, and capital and operating cost estimates.

The results of the engineering study and the preliminary cost analysis were combined to compare energy costs obtainable from the proposed plants with prevailing costs of conventional energy sources.

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EXECUTIVE SUMMARY

The Ontario Ministry of Energy has identified immediate and long term opportunities for the conversion of wood waste into fuel. In a March 24, 1980 policy statement, Energy From Waste: A Program for Ontario, the Ministry of Energy stated that, using currently feasible technology, more than 2% of Ontario's total energy supply could be produced annually by 1995 from wood residues and wood (hybrid poplar) energy plantations. The counties of Leeds, Grenville and Lanark in Eastern Ontario have been identified as areas with a potential for supply of wood for conversion into electricity, steam and methanol.

A study was initiated in June 1980 by the Ontario Ministry of Energy in cooperation with the Ministry of Natural Resources and the Ministry of Treasury and Inter-governmental Affairs to investigate the technical and economic feasibility of converting wood into energy in these three counties. Completed in May 1981, the Phase I report concluded that the area is capable of generating over 1 million oven dry tonnes a year at a cost of approximately $50 per oven dry ton. It also concluded that it is technically feasible, using commercially available techniques, to develop a power plant with the capacity up to 50 megawatts to generate electricity and steam power. Finally, it was concluded that it is technically possible using a prototype gasification system developed by Omnifuel to produce methanol. Perth, Carleton Place and Edwardsburgh were chosen for further investigation as possible sites for the location of an electrical power station, a co-generating facility, and a demonstration size methanol plant.

In support of the recommendations of Phase I, Phase II conducted a preliminary engineering design and cost analysis for:

- a 10-MW electric power plant at Perth or Carleton Place;
- a 9-MW co-generating facility, producing electricity and steam, at Edwardsburgh; and

- o a 60-ton per day methanol demonstration unit which could be located at any of these three sites.

The Phase II report estimated the current and future demand for fuel wood for residential, commercial and institutional buildings in the area. Wood requirements are expected to increase from 330,250 oven dry ton per year in 1980 to 404,000 oven dry ton per year by 1990. These estimates were based upon reasonable assumptions regarding future trends for alternative energy prices, the development of new technologies for burning fuel wood, and the potential impact of Government incentive programs (e.g. The Canadian Oil Substitution Program).

This report provides an engineering analysis at the pre-feasibility level. The detailed engineering work was carried out by Shawinigan Energy Consultants Ltd. Included are process flow diagrams, plant layout diagrams, schematic diagrams of major capital equipment to be used, lists of capital equipment, and estimations for capital and operating costs. The results of this engineering analysis is summarized in the table below.

	Type of Facility		
	10MW Steam Turbine	9MW Cogeneration	60TPD Methanol
		(1981 $)	
Capital Cost	$12.7 mill.	$16.4 mill.	$36.0 mill.
Annual Operating Cost	$ 3.2 mill.	$ 5.9 mill.	$ 4.0 mill.
Cost of Electricity (per kWh)	7.15¢k	2.73¢	-
Cost of Steam (per MM BTU)	-	$ 4.89	-
Cost of Methanol (per litre)	-	-	40¢

The development of a 9MW co-generating facility appears to be economically attractive. Provided site conditions are suitable, this project provides an excellent example to demonstrate the opportunities for energy production from

wood in the Eastern Ontario region. Although the economics of producing methanol are weak at this time, the project merits consideration as a demonstration of the technological possibilities of producing methanol from wood. Moreover, the anticipated escalation of conventional fuel prices in the future should enhance the potential for producing methanol from wood at competitive prices.

Finally, the report concludes that further consideration should be given to the development of an energy complex involving a co-generation plant and a methanol plant in the Region.

1.0 INTRODUCTION

This is the Phase II Report of a study investigating the technical and economic feasibility of converting wood into energy in Eastern Ontario.

The Phase I report, entitled "Wood Supply, Conversion Technology and Markets", recommended an engineering design and cost analysis of:

- a 10-MW electricity generating capacity at Perth or Carleton Place;
- a 9-MW steam and electricity facility at Edwardsburgh; and
- a 60 tons per day methanol plant to be located at Perth, Carleton Place, or Edwardsburgh.

The Phase II report provides the engineering and preliminary cost analysis of the above proposed plants for each location.

Study Approach

The engineering work is conducted at a pre-feasibility level using commercially available costs for raw materials, capital equiment and labour. The study draws substantially on work previously conducted for the Hearst Wood Waste Energy Study (January 1979)(1). The Hearst Study examined the feasibility of developing wood burning plants of a slightly larger scale and of a somewhat similar design concept as proposed in this study. Therefore, it was proposed by the client committee that consultants should integrate and incorporate work previously completed in the Hearst study wherever possible and applicable.

This present study has been undertaken in somewhat of a different context than the Hearst study. Specifically, since the release of the Hearst study:

- the Ontario Government has strengthened its commitment to the integration of new energy sources into the Ontario Hydro System; in

particular, energy from waste and wood wastes has been given higher priority in the Government's drive for greater self-sufficiency;

- o world oil prices have more than doubled and Canadian oil prices have also risen, giving greater impetus to the viability of a wood fired energy plant;

- o Ontario Hydro has undertaken a review of its policy towards the purchase of energy from non-conventional sources of power with a view to accomodating the development of wood fired facilities;

Adjustments to the Terms of Reference

Under the original Terms of Reference for this project, the consultants were requested to conduct a full financial analysis for each plant. This analysis was intended to deal with issues such as debt/equity ratios, tax incentives, subsidies, as well as capturing the impact of changes in the general economic and energy environment. It was the consultant's intention to develop a computer-based financial model in which to evaluate the longer term financial implications of various policy options and to test the economic sensitivity of each plant to changes in government policy and/or prices of competing energy sources.

This consulting engagement was designed to demonstrate the feasibility of deriving energy from wood in the interest of stimulating the private sector to undertake similar projects in Eastern Ontario. However, events have overtaken this project, and there has been sufficient interest expressed by commercial interests in developing such projects in the region. As a consequence, the Ministry of Energy decided, after reviewing the results of Phase II, that there was sufficient engineering analysis and cost information to demonstrate the excellent prospects for developing these energy projects on a commercial basis.

Therefore, in July, 1981, the Ministry decided to accelerate the completion of the entire project and requested the consultants to replace the originally

intended Phase III - a detailed financial analysis and Phase IV - a socio-economic cost/benefit study - with a Summary Report, which is to follow in the near future.

Against this background, the reader is cautioned not to assume that this Phase II report represents a complete financial and economic assessment of the viability of each energy plant. Before any conclusions can be reached in this regard, additional analyses is required especially concerning the impact of changing costs (i.e. wood) and changing prices of competing energy sources. More to the point, further study is required regarding the commercial viability, including an assessment of the financial and commercial risks inherent in the project. Finally, further investigation is needed regarding the most appropriate ownership arrangement. (i.e. private, government or joint ownership) The ownership issue is reflective of the related questions of the degree of commercial viability. In sum, this report represents only a preliminary analysis of the cost of producing energy from wood under economic conditions prevailing in 1981.

Structure of Report

This report is organized in the following way:

- Section 2 provides estimates for wood requirements for each proposed plant as well as for a fuel wood market in Eastern Ontario;

- Section 3 deals with the development of wood harvesting, wood transportation, and plant materials handling systems for each facility;

- Section 4 to 6 provides engineering analysis at the pre-feasibility level including. process flow diagrams plant layout diagrams, schematic diagrams of major capital equipment, lists of capital equipment and capital and operating cost estimates The section

also include preliminary estimates of unit costs of producing electricity, steam and methanol.

- Section 7 uses the results of this preliminary cost assessment to compare energy costs obtainable from the proposed energy plants with those from conventional energy sources;

- Section 8 concludes the report with a discussion of the prospects for converting wood into energy in Eastern Ontario.

2.0 WOOD REQUIREMENTS

In this section, we determine wood requirements for:

1. A fuel wood market for residential, commercial and industrial uses;

2. A 10-MW steam turbine;

3. A 9-MW steam and electricity (cogeneration) plant;

4. A 60 tons per day methanol plant.

2.1 CURRENT DEMAND FOR WOOD

Current Residential Demand for Fuel Wood

According to the 1971 census an estimated 8,000 dwellings or 5% of all dwellings are heated by wood.* Assuming heating requirements of 100 million BTU's per household and a wood furnace efficiency of 50%, the demand for space heating is estimated at 143,000 oven dry tons annually. Cooking and water heating requirements were calculated in a similar manner with a resulting demand of 52,000 oven dry tons.

The 1971 census also revealed that the demand for wood fuel for auxiliary heating purposes was 53,000 fireplaces and wood burning stoves in the region. We assume that consumption averages 2.25 oven dry ton/annum, which translates into approximately 10% of space heating requirements. Accordingly, demand is estimated at 119,250 oven dry tons/annum.

The final component of residential demand is the recreational demand for wood fuel. The Ministry of Natural Resources estimates that the demand for each

* Counties of Leeds, Grenville, and Lanark.

campsite in the region is one oven dry ton/annum which means a total annual demand of 16,000 oven dry tons.

Prior to 1971, there was a steady trend away from wood for space heating and towards oil and natural gas. As a result of the post-1973 changes in oil and natural gas prices, this trend away from wood may have been arrested, possibly reversed. However, there is no published data available to substantiate any changes in trends. Accordingly, we have made the conservative assumption that the level of demand in 1980 has remained relatively unchanged since 1971.

Therefore, the total estimated wood fuel wood market for 1980 is 330,250 oven dried tons yearly or 185,000 cunits. This is detailed in Table 2.1, below.

TABLE 2.1

TOTAL ESTIMATED DEMAND FOR WOOD FUEL
IN LEEDS, GRENVILLE and LANARK COUNTIES, 1980
(Oven Dry Tons)

Space Heating	143,000
Cooling and Water Heating	52,000
Auxilliary Heating	119,250
Recreational Demand	16,000
	330,250

Urban vs. Rural Residential Demand

The primary demand for wood fuel is presently located in rural rather than urban areas. According to the 1971 census, less than 0.5% of dwellings using fuel wood as a primary source of heating are located in cities with populations of 10,000 or more.

There are several reasons for this split in wood fuel usage between the two areas. Rural areas are readily accessible to this source of fuel, especially since many users have ownership rights to the wood. In addition, rural dwellings have sufficient storage areas for this bulky product and in fact, may well carry on their own open air drying. Urban users, on the other hand,

are constrained by their lot sizes for storage and have to rely on relatively small on-site storage facilities. This is in contrast to the use of home heating oil and natural gas which has virtually no storage requirements and is backed up by sophisticated distribution systems that ensure reliable supply.

Total Wood Requirements, 1980

Using the estimates for wood consumption in the operation of the three energy plants, given in Sections 4, 5 and 6, the demand for wood in the study area is summarized in Table 2.2, below.

TABLE 2.2

WOOD REQUIREMENTS, 1980

	ODT/Year	
Requirements for:		
10 MW - Steam turbine	67,000	
or		
9 MW - Cogeneration plant		143,640
60 TPD - Methanol plant	46,000	
Fuel Wood Market	330,250	
Total Demand	443,250	519,890

Depending on which electricity generating plant is developed, total consumption would range from 443,250 to 519,890 ODT for 1980. This latter estimate represents approximately half of the available wood supply at $50/ODT, a third of 20 percent at $75/ODT and approximately 20 percent of the potential supply at $100/ODT(2).

2.2 FUTURE DEMAND FOR WOOD: BASIC ASSUMPTIONS

Wood Prices

In this section, we develop forecasts of future prices of wood in Eastern Ontario based upon reasonable assumptions concerning the increases in cost of delivered wood for the period 1981-1990.

The cost of delivered wood comprises three basic components in approximately the following proportions*:

- o stumpage - 15%
- o harvesting - 50%
- o transportation - 35%

100%

Each cost component is assumed to increase for the period 1981 to 1990 according to the following assumptions

(1) stumpage charges are to increase in line with the general increase in wood products which are assumed to increase at an annual average rate of 10% throughout this period.

(2) harvesting costs are assumed to increase at an annual average rate of 12%, primarily reflecting increases in labour costs.

(3) transportation costs are expected to increase at an annual average rate of 10% in line with expected increases in fuel and other trucking costs.

(4) general rate of inflation is assumed to be 10% per year.

Using these assumptions, the weighted cost of delivered wood is assumed to increase at an annual average rate of 11%. Thus, the level of delivered wood prices in 1981 dollars is expected to be as follows:

	Delivered Cost per ODT (1981 $)
	Residential**
1981	$ 72
1985	74
1990	78

* See Exhibit 3.1 in section 3 for a cost breakdown for each of the main components

** Based on a cost of $55 per full cord of fuel wood. Data supplied by Mr. Firewood Ltd

TABLE 2.3

COMPARISON OF ALTERNATE ENERGY COSTS
(1980 $)

	1980	1985	1990
		($/MM BTU's)	
Light Fuel Oil (#2)	5.09	6.03	6.97
Natural Gas	3.65	4.46	5.27
Wood (Residential)	4.20	4.35	4.60

Assumptions

Oil = 36,735 BTU's per litre
Natural Gas = 1,000 BTU's per cubic foot
Wood = 17,000,000 BTU's per oven dried ton

Prices of Other Energy Sources

The future prices of oil, natural gas and electricity are provided by the Ontario Ministry of Energy (OME) and detailed in the Appendix A. The Appendix contains both a high and low price forecast for each energy source. We have adopted, for comparison purposes, the average between these two forecasts throughout our analysis.

General Rate of Inflation

The analysis conducted throughout is in real prices, i.e. in 1981 dollars. Accordingly, all forecasts are deflated by an assumed rate of general inflation of 10% per year for the 1981-90 period.

Energy Efficiency Assumptions

The final set of assumptions concerns energy efficiency at the "burner tip" of the major competing fuels. We use the following efficiencies:

- 50% for wood;
- 60% for oil;
- 65% for natural gas.

(See Appendix C for details on energy efficiencies.)

Comparison of Alternate Energy Costs

Taking all the assumptions previously stated, we compare alternative energy prices costs for each energy source as burned in Table 2.3, opposite.

Compared to oil, wood is clearly cheaper to burn today and is expected to remain substantially cheaper for the next ten years; by 1990, oven-dried wood is expected to cost $4.60 per MM BTU as burned compared to $6.97 for light fuel oil. Oven-dried wood is slightly cheaper to burn than natural gas. However, this estimate does not include an additional costs associated with

the capital conversion to a wood-burning facility. Nor does it take into account the loss of thermal efficiency when burning green wood.

2.3 FORECAST OF DEMAND FOR FUEL WOOD TO 1990

Residential

The demand for water heating, cooking and recreational purposes have been assumed to remain constant at the 1980 level. The forecast demand for space and auxilliary heating purposes are based on a zero growth in regional dwellings, and as a result any increases in demand must come from increased market penetration of fuel currently in use, i.e. oil.

For space heating, it was demonstrated in Table 2.3, that wood fuel is only price competitive with oil today and as a result, growth in fuel wood demand will come from increased penetration of the fuel oil market. Market penetration rates of 0%, 2.5% and 5% per annum were considered which resulted in annual demand figures ranging from 143,000 to 233,000 oven dry tons/annum in 1990. The 5% growth rate means that 5,000 existing homeowners or 3% of the region, would make the decision to switch to wood fuel, which is overly optimistic. The zero percent growth rate is overly pessimistic in that it does not allow for any growth resulting from government incentives (eg. "off oil" program) and the increasing real cost of oil. The most likely growth will be a medium growth of 2.5% per annum resulting in a 1990 demand for wood fuel for space heating purposes of 183,000 oven dry tons.

The demand for auxilliary space heating was forecast on the same basis, using various growth rates in fireplaces and wood burning stoves. Once again, it was decided that the most likely growth rates would be 2.5% per annum. The combined forecasted figures are given in Table 2.4.

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* Data supplied by a local supplier, Mr. Firewood Ltd.

TABLE 2.4

FORECAST WOOD DEMAND
OVEN DRY TONS, 1990

	Low 0% Growth	Medium 2.5% Growth	High 5% Growth
Space Heating	143,000	183,000	233,000
Cooking and Water Heating	52,000	52,000	52,000
Auxiliary Heating	119,250	153,000	194,000
Recreational	16,000	16,000	16,000
Total	330,250	404,000	495,000

Other Considerations

The demand forecasts are based on the attractiveness of fuel wood from an operating cost view point. It does not consider the capital costs involved in converting an existing heating system to an alternate, nor does it consider the difference in capital costs to install a space heating system in a new dwelling. There has also been no attempt made to quantify the influence of these factors on decisions to switch to fuel wood. In addition, such factors as convenience, cleanliness, the need for storage, reliability of delivery and the energy distribution system in general have not been considered. If these considerations could be factored into the cost comparison, they would serve to increase the cost of fuel wood in comparison to the alternate energy forms as there presently exists no infrastructure for the distribution of the fuel wood on a large scale.

Institutional/Commercial

Although fuel wood is expected to be cheaper than oil and natural gas over the forecast period, demand for fuel wood in the institutional market faces a number of important barriers in penetrating markets, including:

- o increased handling costs of wood compared to oil and natural gas;
- o lack of suppliers able to ensure reliability in terms of volumes and quality;

- the relatively high capital conversion costs from existing oil and natural gas systems;

- necessity of providing storage and financing large wood inventories.

Notwithstanding these factors, there is growing interest in wood conversion in the region, and the Ontario Ministry of Natural Resources is conducting feasibility studies in the area. This ongoing program is encouraging, and preliminary results point to an improved market prospect for wood burning in institutional buildings.

2.4 DISTRIBUTION

Residential

The distribution of wood fuel for rural demand is not of concern at this time. The proximity of the consumer to the source of supply and the availability of their own transportation source are the basic reasons why rural consumption of wood fuel is higher than urban.

Increased efficiency of urban distribution will enhance the penetration of this market. The physical movement of the wood from the rural areas to a central urban distribution centre will not pose any problem, given the relatively low level of demand that exists. Improvements in the handling of wood, such as pellets, bundling, and containerization, will serve to reduce labour requirements and reduce handling costs. As well, such measures will serve to lead to more standardized quantities and quality of wood.

Institutional/Commercial

One of the keys to the penetration of this market is the development of a reliable distribution system. Such a system would provide for the collection of the wood from the various sources of supply and the consolidation of this supply at a central location. A component of the distribution system

could be a facility for drying which would eliminate part of the need for on-site storage at the site of the fuel user. In addition, the system must provide for timely delivery of the fuel and collection of residue from the process.

2.5 TOTAL WOOD REQUIREMENTS, 1990

Table 2.5, following, summarizes total wood requirements for each type of wood conversion facility and for a fuel wood market in 1990. At the $50 per ODT price, (1980 dollars) there is more than sufficient wood biomass available to meet the requirements of the fuel wood market, the methanol plant and either one of the electrical power facilities.

TABLE 2.5

WOOD SUPPLY AND REQUIREMENTS, 1990

I Supply:	Total Supply* at		
	Carleton	Perth	Edwardsburgh
		(ODT/yr)	
Delivered Cost:			
@ $50/ODT	1,062 600	993,800	931,700
75/ODT	1,435,500	1,434,000	1,359,500
100/ODT	1.916,800	1,779,200	1 335,600

I Requirements:	Case A	Case B
	(ODT/Yr)	
1. 10-MW - Steam Turbine	67,000	
2. 9-MW - Cogeneration Plant		143,640
3. 60 TPD - Methanol Plant	46,000	46,000
4. Fuel Wood Market*	404,000	404,000
Total requirements	517,000	593,640

* Medium forecast, Table 2.4.

3.0 WOOD PROCUREMENT TECHNOLOGY

3.1 INTRODUCTION

This section on resource harvesting reviews alternate wood procurement technologies for the extraction and transport of roundwood biomass to steam and electricity generating plants or a methanol plant. Opportunities for integration of roundwood harvesting and utilization of slash and sawmill residues are also explored.

The Phase I report identified the supply of wood biomass readily available as:

- o 400,000 ODT/year from natural forests
- o 91,750 ODT/year from industrial forest residues (exclusive of 23,750 ODT of bark from Domtar)

An additional 130,000 ODT per year of logging residues are potentially available, given certain harvesting conditions.

The sites chosen for the plants are close to existing conversion operations. Although it is difficult to be precise concerning harvesting and inbound transportation requirements without being site specific, the following generalizations appear to apply:

- o surface transport is readily available and for the most part, well developed;

- o forest accessibility will be hampered by the presence of swamp and bog during spring breakup. Furthermore, half-load restrictions will apply on tertiary and secondary roads in the spring. This

will restrict harvesting operations and necessitate building an inventory of wood supplies prior to spring breakup;

- o primary hardwood species for harvesting will be aspen, white birch, maple and basswood.

Since harvesting of timber will occur in "natural" as opposed to "managed" forests, a variety of conditions will apply regarding characteristics of stands to be harvested. In other words, accurate specification of wood procurement technologies and costs will require detailed knowledge of the area to be harvested. Appropriate technologies and related costs will vary, depending upon the following factors: stand density, level of decadence, incidence of large diameter trees, existing road networks, terrain (eg. lakes and rivers, slopes) and provincial harvesting practices.

3.2 WOOD PROCUREMENT TECHNOLOGY OPTIONS

The following section draws heavily on previously published research.(3) In practice, a review of wood procurement technology options necessitates joint consideration of both harvesting and transport alternatives, since wood procurement is best conceived as a single process. Technology options therefore, deal with two problems:

- the tree cutting process itself (including the range of trees and amount of each tree harvested), and

- the stages and methods used to move wood products to the plant(s) (including the degree of processing prior to transport).

The plants evaluated in this study require substantial volumes of wood which will be processed in the form of chips. Unlike a pulp and paper mill, the plants can utilize all parts of the tree, including branches, etc. These considerations suggest the need for an efficient and mechanized harvesting operation geared to "above ground" harvesting of trees. Furthermore, it would be possible to chip the wood in the forest and haul chips (rather than logs or trees) to the plants.

The procurement practices required are not, however, strictly comparable with those followed by other large-scale conversion operations in Ontario, for the following reasons:

1. Existing operations are oriented to harvesting merchantable boles of trees, exluding branches and tops. While utilization standards have improved in the last 10-20 years (due mainly to development of new machinery and construction of integrated forest complexes), full utilization of wood fibre has not yet been achieved. Specifically, problems continue to be encountered in the use of bark for pulping purposes; while in the sawmill industry, branches and tops can not be handled or produce very low grades of lumber.

2. While wood residues are increasingly being utlized for either fuel or chemical feedstock purposes(4), a considerable volume of wood fibre harvested remains in the woods as slash. (For example, the Pulp and Paper Research Institute of Canada estimates that slash ranges from 0.30 - 1.15 ODT per cunit in eastern Canada.)

3. Current wood processing operations are designed to handle specific species. In general, these operations harvest only relatively small volumes of hardwoods. While there are no apparent species restrictions for the methanol or electrical generation operation, restrictions on logging could apply for the following reasons:

   (i) harvesting of trees over 20 inch. dbh., except for cull trees;

   (ii) to the extent that there are provincial policies regulating harvesting of certain species, it is possible that government policy may "set aside" certain species for sawmill use.

In summary, current harvesting operations by pulp and paper mills and by sawmills are not directly applicable to the types of operation under study. Current technology emphasizes a process whereby trees are felled, limbed and

bucked (either manually or by mechanical means), and then are skidded to landings for hauling to mills(5), in either log or chip form. Evidence suggests that the latter technology (using chip vans) is becoming increasingly popular in the United States, especially for hardwoods.(6)

J.P.R. Associates report for the State of Vermont(7), suggest that several different techniques exist for the harvesting of forest biomass for the methanol and electricity plant operations:

1. Complete tree concept -- under this technique, the entire tree (including stump and root system) is utilized in the operation, in order to generate maximum levels of biomass per tree. Currently, machines are being tested in the United States for the harveting of southern pines in this manner, while in Finland, special machines already exist to harvest stump root systems in swamps where they are easy to extract under summer conditions.

2. Above-ground tree concept -- also referred to as full tree harvesting: this technique is similar to that employed in complete tree harvesting, with the important exception that the root and stump system is <u>not</u> removed.

   Above-ground tree harvesting lends itself to the utilization of existing technologies, although special applications are possible (see below). The J.P.R. Associates study, for example, identified two major above-ground harvesting methods -- one using manual felling combined with rubber tired cable skidders for forwarding, and the other feller-bunchers for harvesting and grapple skidders for forwarding.

   Both systems identified by J.P.R. Associates involve chipping at the landing, using whole tree portable chippers, eg. Morbark Total Tree Chiparvestor. Other techniques of handling biomass at the landing are of course possible, eg. transport of full trees to the

mill for ultimate chipping, or transport of de-limbed logs to the mill with processing of remaining slash at the landing.

One special application involving above-ground tree harvesting is the concept of a feller-chipper, i.e. one machine which would fell and immediately chip the full tree in the woods. The chips would be stored in a van attached to the feller-chipper; when the van was full, it would be detached and forwarded to a landing for transport to the mill.

Although prototypes of feller-chippers are known to be under development in France and in Canada at the Forest Engineering Research Institute of Canada (FERIC), technological and economic conditions may inhibit their widespread introduction. In particular, utilization of the full capacity of such a machine would be difficult, i.e. a feller-chipper designed to handle removal of large diameter trees would be severely under-utilized in handling of small diameter trees in the same stand.

3. Tree length logging concept -- the tree length logging concept closely approximates conventional logging practice in Canada, and might for example, include the use of limber-bunchers and similar equipment. Since tree length logging involves leaving slash in the woods, it cannot be considered as a biomass harvesting system. Development of systems specifically geared to the harvesting of this biomass will (according to Professor Harold Young of the University of Maine and other experts) offer far greater potential for cost savings than adoption of tree length logging systems.

The wood procurement methods described in the following paragraphs rely on data developed in the Wood Supply section of our Phase I report.

3.3 PROCURING WOOD BY TYPE OF SUPPLY

Sawmill and Pulpmill Waste

There is little doubt that sawmill residues and bark from pulping operations would be the most reliable and economical source of biomass to the proposed plant. Most of this material is presently wasted, burned or introduced into land fills. At the moment, it can be acquired for a nominal charge and the cost of transport from the sawmill to the plant.

In practice, the successful collection of sawmill residues, be it from a large or small mill, will vary directly with the market price and the ingenuity of the mill owner. No matter how small the mill or how sporadic it operates, virtually all the waste it produces can be saved, accumulated and delivered to a consumer at slightly more than the cost of trucking. With each saw mill it means efficient use of its fork lift and access to an open topped van, which can be conveniently parked at the mill site until loaded. With the larger mills, it means installing additional drive chains, troughts and hoppers for accumulating and loading out residues. The sophistication of this equipment or ancilliary structures will vary directly with the size of the mill.

As was mentioned earlier, the cost of these residues is primarily the cost of transport from the sawmill to the plant. Presently, each sawmill and the one pulpmill in the study area which develops bark, experience a disposal cost, the recapture of which all would welcome. The initial price paid to the producer therefore would no doubt be nominal and negotiable. Regardless, it should be lucrative enough to develop long term contracts of supply. It is assumed $5/ODT would be sufficient to attract 50% of the available volume. This amounts to 45,875 ODT/year, exclusive of any bark obtained from the Domtar pulp mill in Cornwall.

Hauling costs for this material were calculated in the Phase I report to be as follows in Table 3.1:

TABLE 3.1

Sawmill Residues

Average Haul Distance and Cost/ODT

Plant Site	Average Haul Distance (KM)	Miles	Cost Per Green Ton Loaded Mile	Haul Cost/ Green Ton	Total Average Cost/ODT
Edwardsburgh	(223)	139	.06	8.34	$19.18
Perth	(142)	88	.09	7.92	18 46
Carleton Place	(124)	77	.09	6.93	16.78

Logging Residues

The estimated 130,000 ODT of logging residues produced annually in the study area is without a doubt an attractive source of biomass. However, to believe that all of this volume is readily attainable is unrealistic and impractical. Before such can be recovered basic philosophies of harvesting must change from that of harvesting prime values to that of harvesting volume alone while maintaining the optimal residuals for each growing site. The increasing economic value of wood for energy may help to change from an exploitation philosophy to one of stand improvement. By doing so it is felt that quantities and quality of supply for industrial products can eventually be enhanced.

Regardless, the crux of the problem lies with the mechanics and method of harvsting. An efficient logging complement of men and equipment must be financed, assembled, and organized to render the least cost of production. It must be large enough to support both key machines - the whole tree chipper and the sawlog loading unit. Economy of scale requires that the skidding component at least equal that depicted in the two cases illustrated in the natural biomass harvesting discussed later.

The method of harvesting is equally as important. Logging residues created today are lost forever. This material can be recovered most economically

while it is being created. There is no alternative to the "one pass" logging system with and whole tree chips. While good stand management and economics favour harvesting by large operators, there is opportunities for small operators, family groups and individuals. Recovery of this potential supply however, remains in the future until the price for wood biomass favours its harvest. Only then will logging companies and smaller operators utilize this supply.

Natural Biomass

The remaining portion of the biomass requirement, 211,465 ODT come from the natural forest. The Phase I report indicated that some 37.5% of the available natural biomass will come from clearcutting for stand conversion and the balance from cutting for stand improvement through clearings, thinnings and selective cutting.

Stand Conversion

In this case, the low grade forest stands of limited potential would be clearcut using crawler mounted feller bunchers and skidded to the landings using clambunk skidders. At landings, any sawlogs would be bucked out of the trees and the remainder would be fed into a mobile chip harvestor. It is estimated that approximately 1 cunit of sawlogs would be developed for each acre harvested. These would be sold at the landing.

To the extent that the Forest Act places restrictions on the land for purposes other than forestry, it is proposed that plant management should enter into a lease arrangement with the landowner. This agreement would allow the owner to receive a normal stumpage for the timber removed and a nominal rent for a ten year period. Plant management would be responsible fo the earliest possible planting of the cleared land with domestic hybrid poplars or whatever other species of tree is most suitable to the site.

Stand Improvement

In this case, the plant management would probably be best advised to enter into a simple stumpage purchase agreement, since as a result of the stand improvement practices, the final crop would have higher end-uses than as biomass chips.

In order to cause minimal damage to the residual trees in the stand, rubber mounted feller bunchers would have to be used and skidding would have to be done with small grapple skidders, which would deliver the material to a chip harvestor at the landing.

The present stumpage paid to land owners for pulpwood is $6 per cord and buyers are meeting their requirements. Depending on whether the pulpwood is coniferous, poplar or mixed tolerant and other hardwoods the actual price per oven dry ton ranges from $10.00-6.00. For the purposes of this feasibility study, we have assumed an average stumpage price of $6/ODT in the cost calculations. However, stumpage charges are continually changing, and efforts are being made to increase charges over time in order to improve the rate of return to the grower. Should higher stumpage charges evolve, the delivered cost of wood would correspondingly increase.

A summary of the estimated costs of this operation is presented in Exhibit 3.1, opposite.

Average Delivered Cost of Natural Biomass

The delivered cost per oven dry ton of natural biomass is shown in Exhibit 3.2, following.

3.4 TRANSPORTATION AND MATERIAL HANDLING

The cost of transporting biomass to a conversion plant will vary directly with distance, the capacity of the hauling unit and the species being transported. Presently, the conventional truck operating in southeast Ontario is a semi-trailer, 30-ton chip van. Although there are other options

EXHIBIT 3.1

Summary of Annual Operating Cost Estimates for Natural Biomass Extraction

1. Gross Annual Production: 212,000 ODT or 360,400 green tons
   Annual production/site = 48,000 G.T.

2. Estimates include owning costs on all equipment.

3. Case No. 1 - Clearcut for stand conversion - 2.8 sites
   Case No. 2 - Selective cut for stand improvement - 4.7 sites
   7.5 contractor operated sites.

4. Estimates in 1980 dollars.

	Case No. 1		Case No. 2	
	$/year ('000)	$/GT	$/year ('000)	$/GT
Annual harvest	135,150 GT		225,250 GT	
Item				
1. Fellers, bunching fordwarding and chipping	1,142.0	8.45	2,083.6	9.25
2. Support, moving and transport	54.1	0.40	90.1	0.40
3. Road, landing and trail construction, logging planning	27.0	0.20	45.1	0.20
4. Supervision and camp burden	128.4	0.95	270.3	1.20
Subtotal	1,351.5	10.00	2,489.0	11.05
5. Overhead, profit and risk (20%)	270.3	2.00	497.8	2.20
Cost at Roadside	$1,621.8	12.00	$2,986.8	13.25
Total Costs			$4,608,600	

Weighted average cost/green ton	$12.79
Weighted average cost/oven dry ton (f=1.7)	$20.74
Stumpage/ODT	$ 6.00
Total weighted average cost/ODT at roadside	$26.74

Totals do not add due to rounding.

EXHIBIT 3.2

Total Delivered Cost/ODT for Natural Biomass (Annual Basis)

	Edwardsburgh	Perth	Carleton Place
Cost at Roadside, including stumpage	$26.74	$26.74	$26.74
Weighted average one-way haul distance	117 mile	71 mile	80 mile
Cost/ODT loaded mile	$0.119	$0.17	$0.153
Chip hauling cost	$13.92	$12.07	$12.24
Total delivered cost	$40.66	$38.81	$38.98

EXHIBIT 3.3

TRANSPORTATION REQUIREMENTS FOR PROPOSED PLANTS

Type of Plant	Requirements for Initial Inventory		Requirements for Operations	
	Wood (green tons)	Transport (truck loads per day for period of 1 year)	Wood (green tons per day)	Transport (truck loads per hour)
Electricity	32,000	7	514	2.6
Cogeneration (steam and electricity)	61,046	12	977	5.0
Methanol	19,550	4	313	2.0

Assumptions:

a) **Capacity**
- o chipper capacity of 19 GT/hr
- o trailer capacity of 20 tons (wood chips approximately 20 lb/cubic ft 2,000 cubic feet of capacity)

b) **Truck Operations**
10 hrs/day; 250 days/yr.

c) **Trip Times**
Round trip from site to Carleton Place.
70 km @ 75 km/hr = 1 hr. + 15 min. unload
Round trip from site to Perth and Edwardsburgh
75 km @ 75 km/hr = 1 hr. + 15 min. unload
Chipper will fill van in approximately 1 hr. 5 minutes.

available, namely: larger semi-trailer vans and truck and pup-trailer combinations; it was assumed for this study, that haul rates should reflect the operating costs and capacities of equipment available in the region today as well as the net weight hauled in oven dry tons, depending on the species or species groups being tansported. The following relationships were employed to modify haul rates appropriately throughout this text:

1 Cord poplar	= 1.3 O.D.T.
1 Cord confirs	= 1.2 O.D.T.
1 Cord-mixed tolerant hardwoods	= 1.6 O.D.T.

Exhibit 3.3, opposite, presents transportation requirements for the preparation of an inventory and for operations in each type of plant proposed. (Requirements for wood are given in Section 3.) The scale of operations for each plant presents no difficulty with respect to the physical delivery of wood for inventory and operations.

Average Plant Cost

The total weighted average cost for biomass fuel at each plant location is estimated to be:

Average Cost/ODT	Edwardsburgh	Perth	Carleton Place	Average
	$35.44	$33.87	$33.59	$34.30

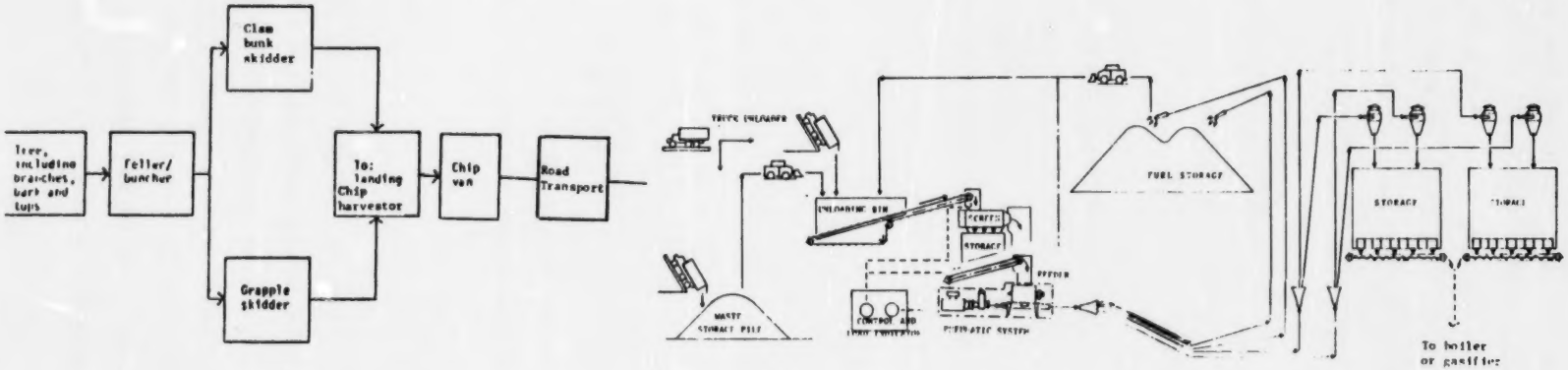
The estimate of $34.30 is used throughout the subsequent analysis.

Plant Material Handling

Material would be delivered in chip form to the plant. Chip vans would be emptied via a van tipper and the chips moved by front end loader or conveyor to either the "hot" storage yard for almost immediate feed to the plant chip bin or else may be diverted to the "sold" storage yard for later use. A minimum three month supply of chips will be required at the plant site to allow for supply problems in the woods and to dry the chips. A schematic of the total chip supply process is provided in Exhibit 3.4, following.

EXHIBIT 3-4

SIMPLIFIED OUTLINE OF WOOD PROCUREMENT SYSTEM



3.5 WOOD PROCUREMENT MANAGEMENT

All harvesting operations would be conducted by contractors. Plant management would contract with companies to supply the plant with specific volumes at specific prices, F.O.B. plant. The contractor would therefore be responsible for locating sources of supply and arranging the terms of sale from individual owners. It is probable that plant management would play some part in these negotiations in terms of guaranteeing reforestation operations.

Plant management would not be responsible for financing equipment purchases or leases, although the contract prices paid for the biomass would reflect these charges. This method of managing wood supply is typical of the forest industry in eastern Ontario.

4.0 SCHEME I 10-MW STEAM TURBINE PLANT[8]

4.1 BASIS OF DESIGN

In accordance with the recommendations of the Phase I report, the size of the proposed power generating plant is 10 MW, as compared to the 20-50 MW range indicated in the original Terms of Reference of the study. Furthermore, the design of the plant has been modeled after the Hearst Study.

This is a very small power plant by today's standards and therefore is penalized by the adverse economies of scale.

4.2 SELECTION OF STEAM PARAMETERS

Three sets of parameters have been considered: 600 psia/750°F; 800 psia/800°F; and 900 psia/900°F; each combined with 2" and 2.5" Hg condenser pressure. As the parameters increase, the required steam flow rates decrease in the ratio of: 1.110 to 1.055 to 1.0. So does the cooling water flow rate. The overall thermal efficiency of the schemes is, however, nearly the same and the cost differences are small either way. Therefore, in order to extend the validity of the data developed in the Hearst Study, the present scheme is based on the following data:

Live steam conditions at boiler	950 psia, 910°F
Turbine throttle steam	900 psia, 900°F
Condenser pressure	2" Hg
Power output	10 MW

4.3 FLOW DIAGRAM

The flow diagram, Figure 4.1, following, contains parametric data on the steam cycle prevailing at the design conditions. Four parameters are given at every point of change, namely: mass flow rate, pressure, temperature and specific enthalpy. These data form the basis of equipment sizing and the

mass/enegy balance calculations which are summarized in the following sections.

Two-stage feedheating is used in addition to the gland condenser: a direct contact heater at 25 psia and a feedheater to raise the temperature to 300°F The make-up water is assumed to be 2%, to cover blowdown and steam losses. The electrical output amounts to 10,650 KW with a turbine of average efficiency.

4.4 ENERGY BALANCE AND THERMAL EFFICIENCY

The heat balance is based on the flow diagram and the following conditions:

Heating value of chips (bone dry)	8500 BTU/lb.
Moisture content	49%
Boiler efficiency	65%

1. Heat input to boiler:

$$\frac{90{,}000 \times (1456 - 269.7)}{0.65} = 164.258 \times 10^6 \text{ BTU/HR.}$$

2. Wood chips equivalent (dry):

$$\frac{164.258 \times 10^6}{2000 \times 8500} = 9.66 \text{ ODT/HR.}$$

3. Generator output: 10,650 KW

4. Less: In-plant power demand: 650 KW

5. Net electrical output: 10,000 KW

6. Overall thermal efficiency:

Gross $\frac{10{,}650 \times 3413}{164.258 \times 10^6} \times 100 = 22.13\%$

Net $\frac{10{,}000 \times 3413}{164.258 \times 10^6} \times 100 = 20.78\%$

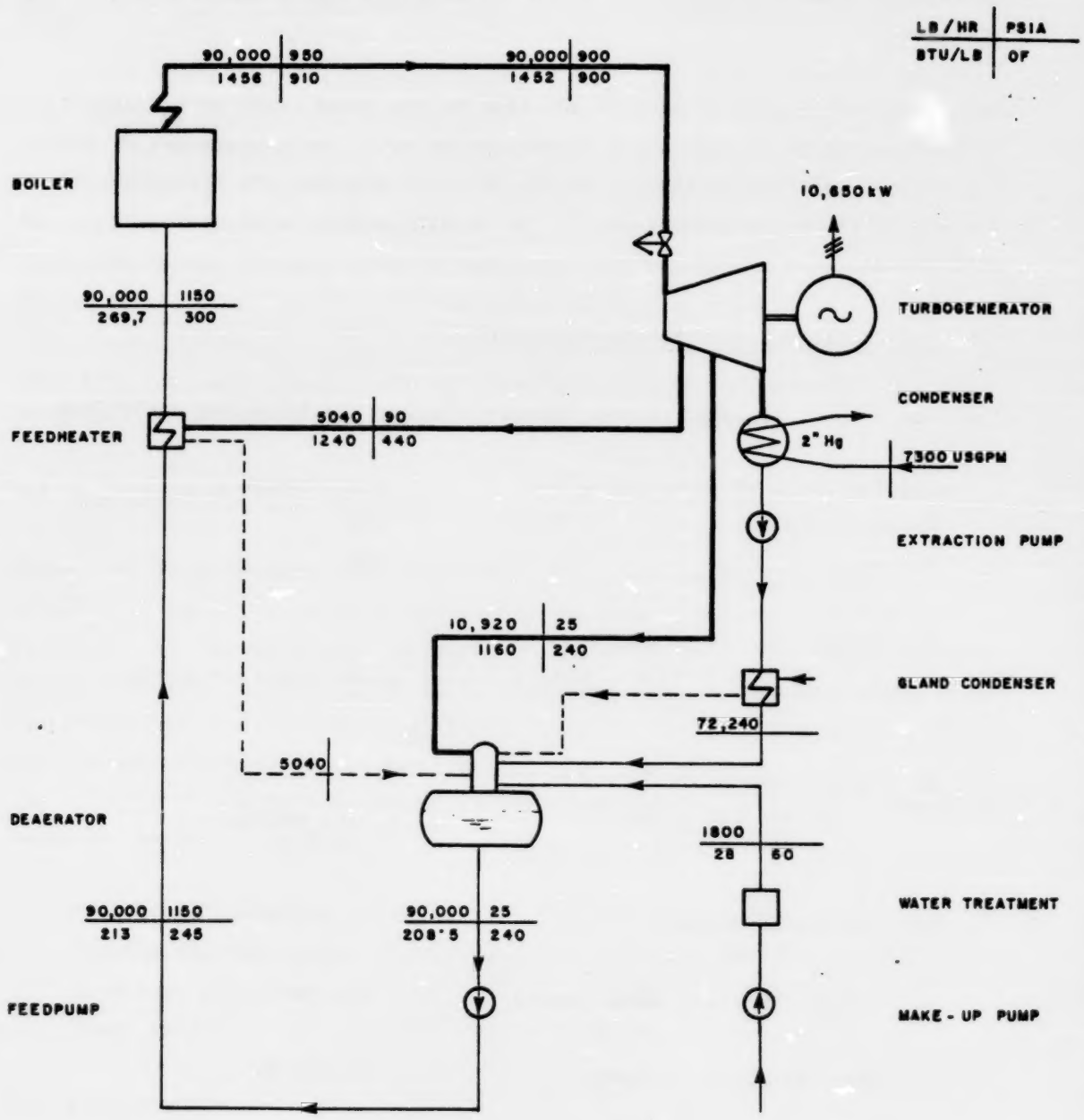


FIG. 4.1 10-MW STEAM POWER PLANT

Annual Energy Balance

The plant is assumed to operate as a base load plant with 80% annual capacity factor.

The annual electrical output is:

8760 x 0.8 x 10,000 = 70.08 million KWH

The corresponding fuel input required is:

7008 x 9.66 = 67,700 ODT/year

The ash disposal amounts to: 2100 tons/year

4.5 COST ESTIMATE

Major Equipment

The amount of wood burned in the plant is only 40% of what was required in the Hearst plant. The wood handling and ash removal system are, therefore, only half the size of the Hearst plant, but otherwise similar, with the exception that the municipal waste handling is deleted here. Furthermore, a hog would not be necessary.

The steam generator is rated for 90,000 lbs./hr. steam at 950 psia, 910°F. It is a field erected unit complete with spreader stoker, water cooled furnace, evaporator, superheater, economizer and air heater, fans and ducts, mechanical dust collectors, soot blower, structural steelwork, ladders and walkways, piping, fittings, insulation, etc. The boiler is equipped with natural gas burners for start-up and with combustion controls and instrumentation.

The turbine is rated for 90,000 lbs./hr. steam throughput at 900 psia, 900°F throttle steam and 2" Hg condenser pressure. The design and cost estimate is based on the Westinghouse Model M25 unit.

With the exception of the two-stage feedheating, the design is similar to that of the Hearst Study.

Capital Costs

The capital cost estimate is based on current budget prices provided by manufacturers of the boiler and the turbogenerator. Other costs are derived from the Hearst study. The breakdown is as follows:

	Item	1981 Dollars
1.	Steam generator with auxiliaries	3,200,000
2.	Instrumentation and controls	400,000
3.	Turbine-generator with auxiliaries	2,000,000
4.	Pumps, compressors with drives	180,000
5.	Miscellaneous equipment, crane, etc.	120,000
6.	Water treatment system	70,000
7.	Cooling water system	200,000
8.	Piping, valves, insulation	1,000,000
9.	Electrical system	900,000
10.	Wood and ash handling system	1,050,000
11.	Buildings and structures	1,300,000
12.	Sub-Total	10,420,000
13.	Engineering and supervision	1,080,000
14.	Contingency	1,200,000
15.	Estimated Total	12,700,000

Operating Costs

The breakdown of operating costs is as follows:

Item			1981 Dollars
Wood Fuel - 67,700 ODT/year @ $34.30*			2,322,110
Ash disposal			15 000
Operating staff:			
(1)	Superintendent	30,000	
(5)	1st class operators	120,000	
(5)	3rd class operators	90,000	
(4)	Shift maintenance	85,000	
(6)	Woodyard crew	108,000	
(2)	Clerks	20,000	
(23)	Total		453,000
Maintenance labour materials			300,000
Administration and general			110,000
Insurance			30,000
TOTAL			3,230,110

4.6 COST OF POWER

The derivation of the unit cost of electricity is as follows:

Capital charges 14% (excluding depreciation)	$1,778,000
Operating costs	3,230,110
Annual costs	$5,008,110

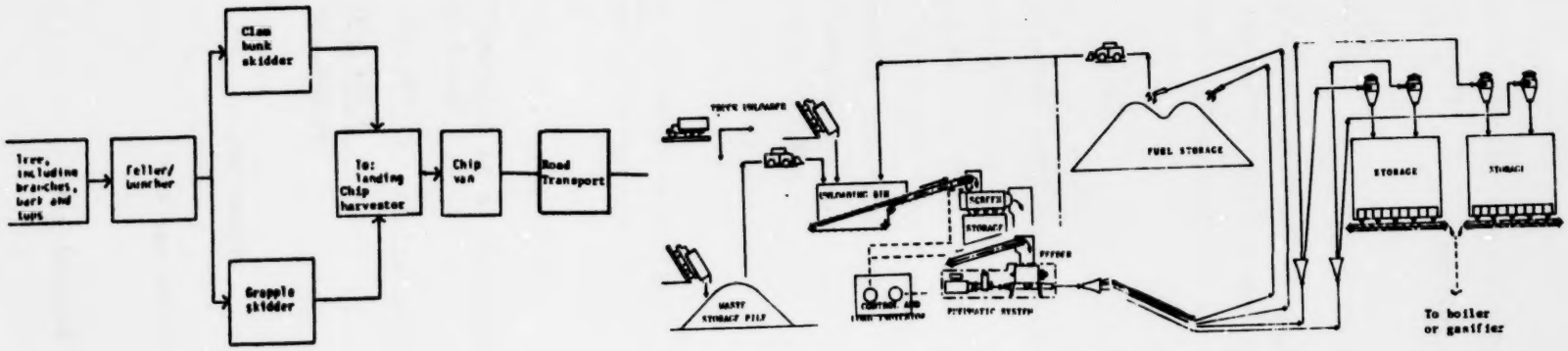
Net power generation 70080 MWh

Unit cost: $\frac{5,008,110}{70,080,000} = 0.0715$ or 7.15¢ per kWh

* For a derivationn of this cost, see Section 3.4.

EXHIBIT 5.1

SIMPLIFIED OUTLINE OF WOOD PROCUREMENT SYSTEM



5.0 SCHEME II 9-MW COGENERATION PLANT

5.1 BASIC PARAMETERS

The Canada Starch plant at Cardinal, Ontario is used as a typical example in this scheme.

The information obtained on the plant is as follows:

Operation:	Continuous, 24 hours per day, year round.
Steam:	170,000 lbs./hr. maximum; 140,000 lbs/hr. average at 150 psi.
Electricity:	9-MW peak demand, 8-MW average demand.
Annual Power Consumption:	59 million KWH.

Present fuel is natural gas with Bunker "C" standby. There are three boilers: two, 100,000 lbs./hr. each and one 30,000 lbs./hr. capacity. process steam demand and power demand are fairly constant during the year. Space heating and water heating requires more steam in the winter thus causing the maximum demand. The plant 200 USGPM warm water at 120°F in the process and 100 USGPM cold water for pump seals and cooling. The water is taken from the river, chlorinated and zeolite softened for the application. Live steam is used almost everywhere and flash steam is available for water heating. The condensate return averages 50 percent. There is a 600 KW generator driven by a backpressure turbine which requires about 25,000 lbs./hr. steam, and four old steam engines requiring 10,000 lbs./hr. steam. These prime movers are seldom used these days, although the condition of the backpressure turbine is fairly good.

Exhibit 5.1 outlines a wood procurement system for this plant.

5.2 SELECTION OF LIVE STEAM PARAMETERS

An assessment of alternative live steam parameters for the cogeneration scheme showed that:

- the choice of 600 psia/750°F leads to an extraction-condensing turbine, where the process steam yields only 4.5 MW cogenerative power, which leaves an equal amount to be generated in the condensing mode;

- when choosing 900 psia/900°F live steam conditions, the cogenerative portion increases to 6 MW and the condensing portion drops to 3 MW;

- by raising the parameters to 1250 psia/910°F and with the use of an efficient back pressure turbine, the cogenerative power output increases to 9MW, which is sufficient to meet the electrical demand of the plant.

Thus, the design reported herein is based on the following data:

Live steam conditions at boiler	1250 psia, 910°F
Turbine throttle steam	1200 psia, 900°F
Turbine backpressure	180 psia
Steam sendout to process plant, maximum	170,000 lb/hr
Steam sendout to process plant, average	150,000 lb/hr
Condensate return rate	50%

5.3 FLOW DIAGRAM

The flow diagram, Figure 5.1, following, contains parametric data on the steam cycle prevailing at the design conditions. Four parameters are given at every point of change, namely: mass flow rate, pressure, temperature and specific enthalpy. These data form the basis of equipment sizing and the

mass/energy balance calculations which are summarized in the following sections. The main considerations which have influenced the design are as follows.

The live steam parameters are so selected that a backpressure turbine can be used, instead of an extraction-condensing turbine. This minimizes the cost, but introduces a rigid correlation between the process steam flow and the electrical output. Another consideration is to maximize the power/steam ratio. This ratio for the process plant is prescribed by the design data, namely: 9000 KW at 170,000 lbs./hr. steam flow. The power/steam ratio can be improved by creating an internal steam demand and by reducing the auxiliary power demand simultaneously in the cogeneration plant. This is possible through intensive feedheating and the use of a turbine driven feed pump. Accordingly, two-stage feedheating is employed which requires some 28,000 lbs./hr. steam to be used internally in the feedheater and the deaerator, respectively. The rigid correlation between process steam flow and electrical output can be broken with the use of a feedwater accumulator. It is now possible to obtain a steady electrical output while the process steam flow varies, and vice-versa. For example, the generator output may remain unchanged at 9100 KW, while the process steam flow varies, between, say 150,000 and 170,000 lbs./hr. Conversely, it is possible to generate electricity between, say 9600 KW and 8600 KW, while the process steam flow remains unchanged at 160,000 lbs./hr. The time period within which such manipulations can be maintained depends on the volumetric and thermal sizing of the accumulator. During these manipulations the accumulator will be charged or discharged automatically through its control system.

The eventual sizing of the accumulator is, of course, subject to detail engineering, in the event of an actual installation. The concept outlined here is merely an illustration of the flexibility that can be obtained with heat or steam accumulators in an industrial cogeneration plant. The concept is frequently used in Europe and a Canadian application of it exists in the Quebec City Incinerator Plant.

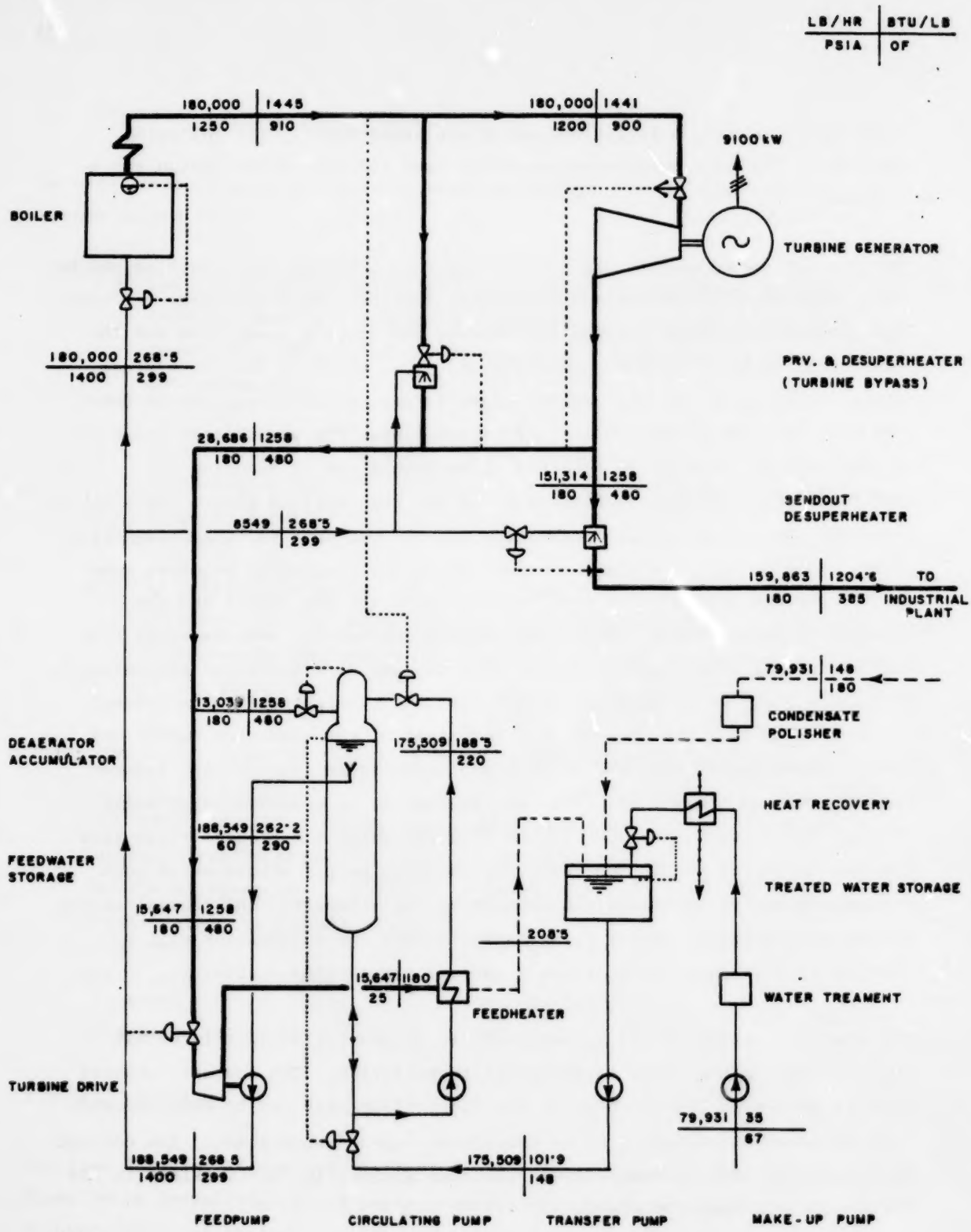


FIG.5.1 9-MW COGENERATION PLANT

The exhaust steam leaving the backpressure turbine is desuperheated to suit the requirements of the process plant. During an outage of the turbogenerator, process steam is provided via the pressure reducing and desuperheating station. The sendout steam and the condensate return are metered for the purpose of billing.

Make-up water is taken from the river. Pretreatment includes: clarifiers and gravity filters as well as chemical feeders. The condensate return is polished. The boiler feedwater is then demineralized, preheated and deaerated. The feedpump delivers the water to the boiler at approximately 300°F temperature.

5.4 ENERGY BALANCE AND THERMAL EFFICIENCY

The heat balance is based on the flow diagram and the following conditions:

Heating value of chips (bone dry)	8500 BTU/lb.
Moisture content	49%
Boiler efficiency	65%

1. Heat input to boiler:

$$\frac{180{,}000 \times (1445 - 268.5)}{0.65} = 325.8 \times 10^6 \text{ BTU/HR.}$$

2. Wood chips equivalent (dry):

$$\frac{325.8 \times 10^6}{2000 \times 8500} = 19.165 \text{ ODT/HR.}$$

3. Heat output to process plant:
   (steam sendout minus condensate return)
   $159{,}863 \times 1204.6 - 79{,}931 \times 148 = 181.23 \times 10^6$
   Less transmission heat loss: 2% = 3.63
   177.60×10^6 BTU/HR.

4. Electrical output to process plant:
   (generator output minus in-plant use)
   $9100 - 650 = 8450$ KW

5. Net thermal efficiency:

$$\frac{177.60 \times 10^6 + 8450 \times 3413}{325.8 \times 10^6} \times 100 = 63.36\%$$

Annual Energy Consumption and Production

The process plant is assumed to operate year round with two weeks shutdown for general maintenance, or 8424 hours per year. The planned outage of the power plant will coincide with the shutdown of the process plant.

The availability of the boiler plant is assumed to be 8424 x 0.948 = 7986 hours in a year. The availability of the turbogenerator plant is assumed to be 8424 x 0.948 x 0.980 = 7826 hours in a year. The availability factors of a single boiler and single turbine are from the HEARST STUDY.

The average steam sendout rate is assumed to be 150,000 lbs./hr., corresponding to 8530 KW generator output and 7900 KW net electrical output.

The annual heat sendout to the process plant with 50% condensate return is, therefore:

7986 x (150,000 x 1204.6 - 75,000 x 148)	= $1,354,346 \times 10^6$ BTU
Less 2% transmission heat loss:	$\underline{27,086}$
Resulting in heat sale of:	$1,327,260 \times 10^6$ BTU

The annual amount of electricity for sale is:

7826 x 7900 = 61.825×10^6 KWH

During turbine outage (160 hours) and for the 336-hour annual shutdown period, the cogeneration plant will have to purchase electricity from the grid, in the amount of:

160 x 630 + 336 x 250 = 185,000 KWH

The amount of wood chips required for 150,000 lbs./hr. average steam sendout is 17.986 ODT/hr., or in a year:

7986 x 17.986 = 143,640 ODT

5.6 COST ESTIMATES

Major Equipment

The amount of wood required is slightly less than what was required for the 20-MW Hearst plant. The wood handling and ash removal system are, therefore, quite similar to that described in the Hearst report, with the exception of the municipal waste handling which is deleted here. Furthermore, the plant in question would receive wood chips of fairly uniform size, so that a hog would not be necessary. In other respects, the design and costing of the wood and ash handling system follows the Hearst application.

The steam generator is rated for 180,000 lbs./hr. steam at 1250 psia, 910°F. It is a field erected unit, complete with spreader stoker, water cooled furnace, evaporator, superheater, economizer and air heater, fans and ducts, mechanical dust collectors, soot blowers structural steelwork, ladders and walkways, piping, fittings, insulation, etc. The boiler is equipped with natural gas burners for start-up and with combustion controls and instrumentation.

The turbine is rated for 180,000 lbs./hr. steam throughout at 1200 psia/900°F throttle steam and 180 psia backpressure. The design and estimate are based on a radial-flow counter rotation turbogenerator with high efficiency, requiring a simple foundation and proven for industrial application. The generator is rated for 9600 KW at 0.85 power factor, 13.8 KV, 60 Hz. The unit is complete with lube oil and governing oil system, instrumentation and controls, A.C. excitation system, voltage regulator, internal piping wiring, special tools and spanners.

The water pre-treatment system includes: one 16' dia clarifier, two 7' dia gravity filters, four chemical feeders, local controls and interconnecting piping. The condensate polisher includes two-100% sodium cycle polishers for manual operation complete with brine regeneration. The demineralizer system includes two 100% skid mounted demineralizer trains using 48' dia countercurrent units, regeneration system for acid and caustic, control panel and interconnecting piping.

The deaerator is intergrated with the accumulator in a vertical arrangement. The unit is designed for 60 psia operating pressure, 290°F feedwater temperature, capable of absorbing ±10,000 lbs./hr. steam flow fluctuations around the equilibrium steam flow to the deaerator. The complete vessel is made of stainless steel for floor mounting.

The treated water storage tank is of atmospheric design designed for 30-minute retention time.

There are two 100% feedpumps, one turbine and one water driven and two 100% motor driven pumps for the make-up water, the treated water and the accumulator charging.

The electrical system includes: transformers, circuit breakers, disconnect switches, motor control centres, cabling and lighting, D.C. equipment and control boards. The in-plant power demand is estimated at 650 KW when the turbine driven boiler feedpump is in operation and at 1000 KW when it is not.

Capital Cost Estimate

The estimate is based on current budget prices provided by manufacturers of the boiler, turbogenerator, water treatment system, rotating equipment and vessels. The cost of the wood and ash handling system, the structural and civil works are derived from the HEARST study. Piping, wiring, and erection costs are factored estimates, based on similar projects. The breakdown is as follows:

Item	1981 Dollars
1. Steam generator with auxiliaries	5,800,000
2. Instrumentation and controls	400,000
3. Turbine-generator with auxiliaries	2,200,000
4. Pumps, compressors with drives	250,000
5. Miscellaneous equipment, crane, hoists	170,000
6. Water treatment system	480,000
7. Piping, valves, insulation	1,100,000

8.	Electrical system	900,000
9.	Wood and ash handling system	1,200,000
10.	Buildings and structures	1,100,000
11.	Sub-Total	13,600,000
12.	Engineering and supervision	1,360,000
13.	Contingency	1,440,000
14.	Estimated Total	16,400,000

Operating Cost Estimate

The breakdown of operating costs are as follows:

Item			1981 Dollars
Wood Fuel - 143,640 ODT/year @ $34.30*			4,927,000
Ash disposal			32,000
Operating Staff:			
(1)	Superintendent	$ 30,000	
(5)	1st class operators	$120,000	
(5)	3rd class operators	$ 90,000	
(4)	Shift maintenance	$ 85,000	
(6)	Woodyard crew	$108,000	
(2)	Clerks	$ 20,000	
(22)		$453,000	453,000
Maintenance labour and materials			320,000
Administration and general			120,000
Insurance			30,000
ESTIMATED TOTAL			$5,882,000

* For a derivation of this cost, see Section 3.4.

5.7 Cost of Steam and Electricity

In order to establish these costs, the total capital cost and the operating cost should be segregated into two sums, one relating to the production of process steam and the other to the generation of power. The former equals the cost of a low pressure boiler plant and the latter can be obtained by difference. In our case, the two sums are $10.55 million and $5.85 million, respectively, totalling $16.4 million.

The segregation of the operating costs into two sums can be based on the amount of the steam enthalpy used for the one and the other purpose, respectively. From the flow diagram, it can be seen that 1445 - 1258 = 187 BTU/lb heat is used in the turbine and 1258 - 180 = 1078 BTU/lb is used in the process. Thus, the respective percentages are 14.8 and 85.2.

The derivation of the unit cost of steam and electricity can now be done as follows:

Item	Total Cost	Cost for Steam	Cost for Power
Capital charges @ 14% (excl. depreciation)	2,296,000	1,477,000	819,000
Operating Costs	5,882,000	5,011,500	870,500
Total	8,178,000	6,488,500	1,689,500
Process steam produced (net) 10^6 BTU		1.327,260	
Electricity produced (net) MWh			61,825
Unit cost of process steam $ per 10^6 BTU		4.89	
Unit cost of electricity ¢ per kWh			2.73

5.8 Comparison to Hearst Study

In January, 1979, the Ontario Government released the Hearst Wood Waste Study* which examined the feasibility of a cogeneration plant using wood waste from wood products produced in the Town of Hearst, Ontario. The results of that study indicated that electricity produced from a 14 MW cogeneration would be more expensive than a power product from the 9 MW facility examined in this report**. The main difference between the plant proposed in this study and the Hearst project is that our proposed facility features a different engineering design, a back pressure turbine system which is cheaper to build. Other factors contributing to a lower cost of power in this report include the lack of interest charges during construction the lack of depreciation of capital equipment and reduced design and engineering costs.

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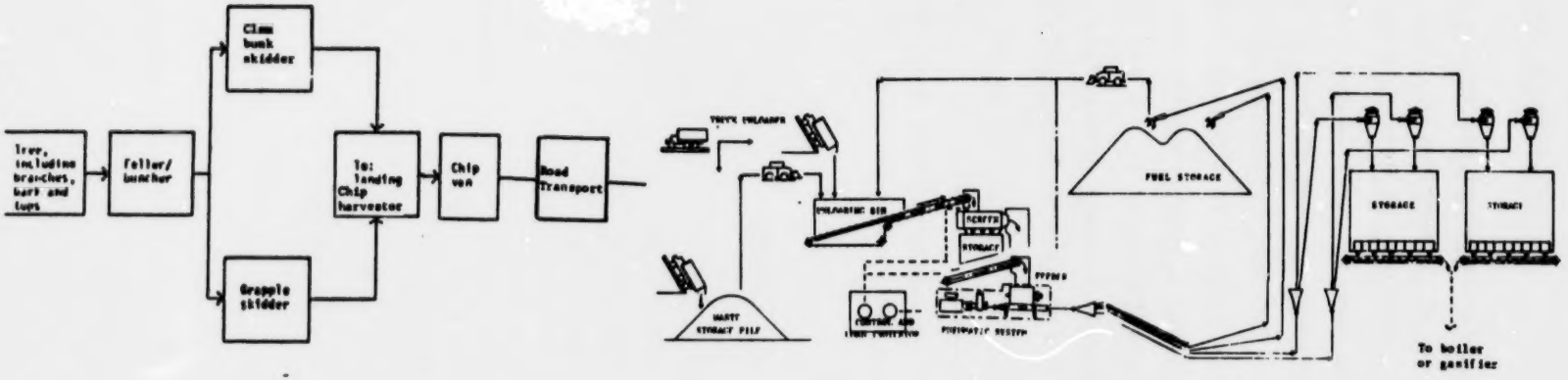
* See reference 1, p.55.

** The Hearst project was estimated to cost $22.6 million (1978 dollars) compared to $16.4 million (1980 dollars) for the 10 MW plant under review here.

EXHIBIT 6.1

SIMPLIFIED OUTLINE OF WOOD PROCUREMENT SYSTEM



6.0 SCHEME III - 60 TPD METHANOL PLANT

6.1 BASIS OF DESIGN

In accordance with the Terms of Reference, the demonstration plant is to yield 60 tons per day fuel grade methanol, using wood chips as the feedstock. The wood required amounts to 46,000 ODT per year. Because of the very small size and the demonstration purpose, the plant is conceived not to be a self-supporting, grass-roots plant which provides its own utilities (steam, electricity) and chemical reactants (oxygen, hydrogen, nitrogen, etc.). This reduces the capital costs. The relatively small quantities of chemical reactants required will be purchased, as part of the operating costs. All steam required will be produced using by-products and wood chips as the fuel. Steam turbines will be used to the extent practicable with the balance of power to be purchased from the electric utility. Cooling water is assumed to be available at the site.

The very small size of the plant has caused special problems in the engineering and costing of the scheme. It is known that wood based methanol plants using modern technology exist on the drafting board only. The size of plant necessary to yield acceptable economic results is believed to be in the upper scale of the 600 to 2400 tons per day range, which is therefore the range used in most studies. A 400 ton per day methanol synthesis plant was the smallest on which reliable and detailed enough cost and performance data could be found in our research. The scaling down to one seventh size requires extrapolation beyond experience.

Exhibit 6.1 outlines a procurement system for this plant.

6.2 SELECTION AND STATUS OF TECHNOLOGY USED

The chemical conversion of wood to methanol involves a succession of processing steps, some of which are commercially proven, while others are not. Essentially, wood must be converted first to sysnthesis gas containing CO and H_2 in the appropriate ratio. This entails the gasification of wood, followed by the cleaning-up of the raw gas and subsequent reforming of

the clean gas through the addition of hydrogen. The components of the gas mixture are then shifted in order to provide the desirable ratio of CO and H_2f required for the formation of methanol. Following the shift reaction, the gas is compressed to the pressure required for the methanol synthesis process. Impurities are then removed including the CO_2 component. In the presence of catalysts, the feedgas in now converted to crude methanol which is then refined (distilled) and upon dewatering the liquid methanol finally emerges.

The gasification of the wood feedstock and the clean-up of the raw gas represents unproven technology. The balance of the processing steps constitutes commercially proven chemical technology, although not with syngas resulting from the gasification of wood. The technological know-how involved in the engineering and the operation of most processing steps is subject to proprietary controls of the process developer or licensor. The cost of proprietary know-how and equipment would, therefore, be subject to negotiations on the royalties to be paid for such know-how, including the use of process design, catalysts, equipment, etc. Herein lies another difficulty in estimating the cost for this study.

The gasification process selected for this application is the OMNIFUEL process, designed by Omnifuel Gasification Systems Limited, Toronto. The first commercial application of the process will go into operation at the Levesque Plywood Mill, Hearst, Ontario, early in 1981. The gasifier will produce low-BTU fuel gas from wood, to replace natural gas in the mill.

The OMNIFUEL gasifier operates on the fluidized-bed reactor concept, which is a well proven concept in chemical process technology. However, this is the first application for gasifying wood feedstock. The fluidized-bed consists of a granular bed of solid particles, such as silica sand. Air is distributed evenly into the bottom of the gasifier and rises up through the bed in air pockets or "bubbles". The wood chips are fed to the bed where turbulent conditions cause rapid heating and mixing of wood and air. The volume of the reactor is small, owing to the very high heat and mass transfer rates, causing short residence time and high throughput. The gasifier is equipped with a surge and metering bin and a feed system designed to deliver

the wood chips directly into the reactor bed. The feed system forms a seal against gas leakage and allows the reactor to the operated under pressure.

Cyclones are provided to recover fly ash and to minimize particulate emission to the atmosphere. The gasifier system is instrumented for automatic operations, including start-up and automatic shut-down should alarm conditions arise.

The thermal efficiency of the conversion is claimed to be 80% plus, and the carbon conversion efficiency higher than 99%.

The first commercial application at Hearst is for the production of low-BTU gas, in which case the reactor is air-blown. For the production of methanol, oxygen blowing is required, as the presence of nitrogen is undesirable in the syngas. Furthermore, the gasifier is to be operated at 250 psig pressure which is necessary for process-economic reasons. The development program for achieving these two goals is underway. Indeed, OMNIFUEL has already made a design of the gasification plant required for the wood-methanol conversion route and estimated its price. That price, which includes the gasifier, the reformer and the shift reactor components, is the basis of the cost estimate in this report.

The final stages of the gasification system are the condensate separation, intermediate compression and the CO_2 absorption components, where existing technology can be used, although some processes are proprietary.

The methanol synthesis portion of the plant is based upon the proven "Low Energy" DAVY POWERGAS/ICI version of the ICI LP methanol process. The process consists of four basic process steps: (1) feedgas purification; (2) compression; (3) synthesis and (4) distillation. This process is proprietary. The cost estimate used herein has been derived from a preliminary cost information provided for a 400 STPD methanol plant.

6.3 FLOW DIAGRAM

The flow diagram, Figure 6.1, following, illustrates the chain of processing steps.

Wood chips are dried to about 15% moisture in a kiln dryer. The feedstock so obtained is introduced in the gasifier, together with oxygen taken from tanker storage. The raw gas is cleaned in separators and passes to the reformer where methane and higher hydrocarbons are converted to CO and H2 by reaction with steam. Heat required for the reactions to take place is provided by the byproducts of the methanol synthesis. Sensible heat from the reformed gas is recovered in a heat exchanger ahead of the shift converter. Here, the ratio of CO and H_2 is altered to suit. The gas pressure is now increased and the CO_2 is removed in the absorber which follows. The absorbing chemical laden with CO_2 is continually regenerated and recycled. The feedgas is now ready to enter the methanol sythesis process.

The gas flows to a knock out drum to remove any entrained liquids and passes to a vessel for removal of chlorides. Upon purification, the gas is compressed to the synthesis loop pressure. An after-cooler removes any moisture still present. The feedgas and gas recycled from the loop enters the circulator compressor. Both compressors are driven by condensing turbines. Syngas from the circulator is preheated by the converter effluent. The converter holds the bed of catalyst. Cooling and condensation of crude methanol occurs in a water cooled condenser. The liquid is flashed at 75 psig in the letdown vessel and passes to a storage tank or directly to the distillation column. Flash gas is recovered as fuel. The crude liquid is first heated then enters the column, where it is refined to fuel grade methanol. Side-streams are collected for use as fuel. The product is stored in tanks.

6.4 MASS AND ENERGY BALANCE, YIELD, EFFICIENCY

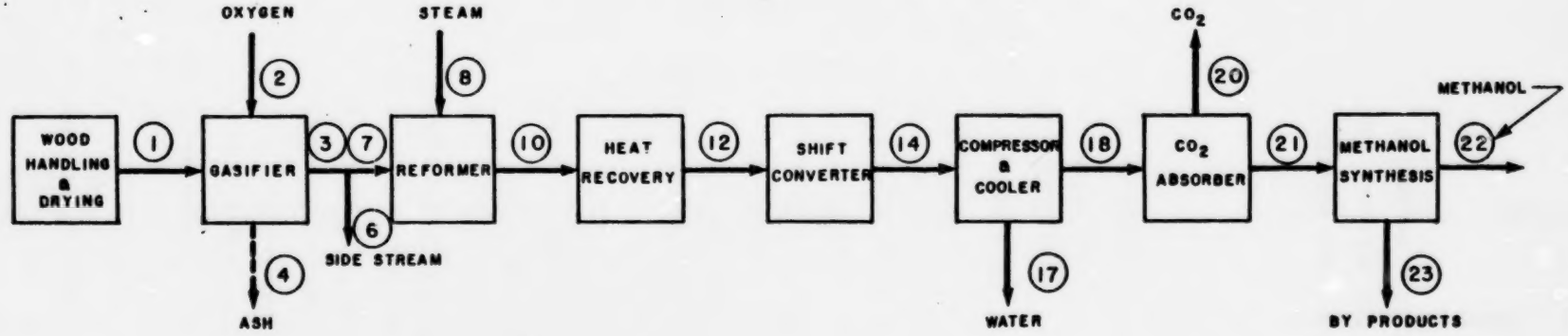
Given below are "composite" energy balances for the system. We describe these balances as "composite" because different parts of the balances are based on different process develops' estimates and predictions regarding

TABLE 6[illegible]

ENTHALPY SUMMARY

STREAM	ENTHALPY (BTU)	TEMPERATURE °F	FLOW DIRECTION	NET ENTHALPY IN PROCESS (BTU)
1. Wood Raw Material	14.3×10^6	60°	I	14.3×10^6
2. Oxygen	0	60°	I	14.3×10^6
3. Gas From Gasifier	13.26×10^6	1,500	T	
4. Ash From Wood	4,500	1,500	0	
5. Heat Removed From Gasifier	1.04×10^6	1,500	0	13.26×10^6
6. 15% Side Stream From Gasifier Gas Fow	1.99×10^6	1,500	0	11.27×10^6
7. Gas To Reformer	11.27×10^6	1,500	T	11.27×10^6
8. Steam to Reformer	1.58×10^6	1,500	I	12.85×10^6
9. Heat to Raise Reformer Temperature	5.25×10^6	1,650+	I	18.10×10^6
10. Reformed Gas	18.18×10^6	1,650	T	18.18×10^6
11. Heat Removed To Cool Gas For Shift Converter	2.11×10^6	1,650-	0	16.08×10^6
12. Gas From Shift Converter	14.76×10^6	500	T	16.08×10^6
13. Heat Removed At Cooler-Compressor	1.43×10^6	500-	0	14.65×10^6
14. Condensate from Cooler-Compressor	1.54×10^5	180	0	14.50×10^6
15. Gas to Carbon Dioxide Absorber	14.50×10^6	180	T	14.50×10^6
16. CO_2 Absorbent Into CO_2 Absorber		180	I	14.50×10^6
17. CO_2 Absorbent From CO_2 Absorber	2.49×10^4	180	0	14.48×10^6
18. Gas Feed To Davy Methanol Process	14.48×10^6	180	T	14.48×10^6
19. Distillation Column Bottoms	4.16×10^3	102	0	14.48×10^6
20. Product Methanol	7.75×10^6	110	0	6.73×10^6
21. Fuel Gas By-Product	3.48×10^6	102	0	3.25×10^6
22. Fusel Oil	1.13×10^5	102	0	3.14×10^6
23. Process Heat Discarded From Methanol Plant	3.14×10^6	110+ or -	0	Zero

I = Into Process: 0 = Out of Process: T = Through Process



STREAM	1	2	3	4	6	7	8	10	12	14	18	20	21	22	23
WOOD	1687														
ASH	30			30											
H_2O	313		359		54	305	1192	1075	1075	1044	29		29		133
OXYGEN		299													
CO			800		120	680		877	877	834	834		834		311
CO_2			838		126	712		1078	1078	1148	1148	832	316		75
H_2			29		4	25		120	120	121	121		121		12
$C_n H_m$			273		41	232									16
CH_3OH														753	
TOTAL	2030	299	2,299	30	345	1954	1192	3150	3150	3150	2132	832	1,300	753	547

BASIS 2000LBS OVEN DRIED WOOD, ASH FREE. FIGURES MEAN POUNDS.

FIG.6.1 60 TPD METHANOL PLANT
BLOCK DIAGRAM AND MATERIAL BALANCE

their process, which at times, had to be supplemented by assumptions on our part in order to provide necessary input for the overall energy balance calculations. The calculations are also preliminary and approximate only. No optimization has been attempted. The overall results appear to be in line with data found in other reports and publications.

The basis for the mass and energy balances are:

- o 2030 pounds of wood feedstock having 30 pounds of ash and 313 pounds of moisture;
- o 60°F enthalpy datum level; and
- o the customary units of measurement.

On that basis, methanol production is projected to be about 753 pounds per 2030 pounds of wood processed. This is a yield of 0.446 pounds of methanol per pound of ash and moisture free wood substance processed. The mass, flow rate, parameters and composition of major process streams are shown in the flow diagram. The heat balance is given in Table 6.1, opposite.

The thermal efficiency of the conversion process is:

$$\text{Cold product efficiency} = \frac{\text{energy in methanol}}{\text{energy in wood feedstock}} = \frac{7.75}{14.3} \times 100 = 54.2\%$$

6.5 COST ESTIMATES

Capital Costs

The capital costs are in current dollars and are derived from discussions with suppliers of proprietary technology. The conventional items are based on in-house records and experience, as described in the power generation schemes. The breakdown is as follows:

	ITEM	1981 Dollars
1.	Wood, ash, and silica handling system.	$ 800,000
2.	Wood-drying equipment.	$ 800,000
3.	OMNIFUEL gasification system, complete with feeder, gas cleaning equipment, reformer and shift reactor.	$ 5,500,000
4.	Compressor and CO_2 absorption system.	$ 1,600,000
5.	DAVY/POWERGAS/ICI Low Energy Methanol Synthesis Plant consisting of purification, compression, synthisis and distillation equipment, storage tanks for crude methanol and product methanol and byproducts including winterization.	$ 9,500,000
6.	Steam and power utilities, cooling water.	$ 3,600,000
7.	General facilities, including site preparation, buildings, potable and sanitary water, electrical distribution, yard piping, lighting, shipping and receiving facilities, process winterization.	$ 4,800,000
8.	Engineering (non-proprietary equipment).	$ 2,000,000
9.	Commissioning and start-up.	$ 4,000,000
10.	Sub-Total	$32,600,000
11.	Contingency	$ 3,400,000
12.	Estimated Total	$36,000,000

Operating Cost

It is assumed that the plant operation is continuous over 330 days in a year with 35 days shutdown for maintenance.

It is further assumed that the plant steam requirements are provided by process heat recovery boilers, the available heat being supplemented by burning the byproducts. High pressure steam at 750 psig is required in the reformer as reactant, in the CO_2 absorber for regeneration of the absorbent, and in the methanol synthesis. Low pressure steam is used mainly for space heating and winterizing. The compressor between the shift converter and the methanol plant is driven by a steam turbine. The compressors in the methanol synthesis loop are motor driven.

PROCESS DESIGN AND MATERIAL BALANCE

The cost of materials, chemicals and utilities required for one year are as follows:

		Cost
1.	Wood Chips @ 2.3 ODT/ton methanol 2.3 x 60 x 330 @ $34.30* =	$1,562,000
2.	Oxygen @ 300 lbs./ODT wood 46,000 x $\frac{300}{2000}$ x 1.1 (factor) x $60 =	$ 455,400
3.	Electricity @ 400 KWH/ton methanol 400 x 60 x 330 x 0.028 =	$ 221,800
4.	Cooling Water 2000 USGPM @ 5¢ per thousand I.G. 2000 x 60 x 330 x 24 x 0.05 =	43,200
5.	Catalysts and chemicals @ $3/ton methanol =	$ 60,000
6.	Ash disposal, silica sand =	$ 15,000

7. Operating staff is based on four shifts of process staff, one shift of specialized maintenance staff and two general maintenance men per shift, two laboratory technicians and supervisory personnel.

No.	Description	1981 Dollars
6	Woodyard crew	$ 108,000
4	Gasification plant operators	$ 100,000
8	Methanol synthesis operators	$ 100,000
8	General shift maintenance men	$ 168,000
4	Specialized maintenance men	$ 108,000
2	Lab technicians	$ 30,000
1	Plant superintendent	$ 35,000
1	Maintenance superintendent	$ 30,000
4	Shift foremen	$ 128,000
1	Lab chemist	$ 25,000
2	Clerks	$ 20,000
41		$ 952,000

	Total Labour Costs	$ 952,000
8.	Administration and office staff	$ 140,000
9.	Maintenance materials and supplies (6% of capital charges)	$ 302,400
10.	Taxes and insurance (4% of capital charges)	$ 201,600
11.	Estimated Total	$3,953,400

* For a derivation of this cost, see Section 3.4.

6.6 Cost of Methanol

The cost of the methanol is very high, owing to the high specific cost of the small scale plant. In order to show this effect, the component costs are expressed as a percentage of the total cost.

Cost breakdown for one ton methanol based on 19,800 tons of methanol produced in a year:

Capital charges @ 14% (excl. depreciation)	$ 254.54	56%
Operating costs	199.67	44%
Total cost per ton:	$ 454.21	100%

Cost per litre: 40.0 cents.

6.7 Summary

Following is a summary of the results of the analysis of the three schemes:

SCHEME I - 10 MW STEAM POWER PLANT

Net electrical output	10 MW
Steam parameters	950 psia, 910°F
Annual wood-chips consumption	67,700 ODT
Annual power output (net)	70,080 MWL
Heat rate (net)	16,424 BTU/kWh
Capital Cost	$12,700,000
Annual operating cost	$3,230,110
cost of electricity	7.15¢ per kWh

SCHEME II - 9 MW COGENERATION PLANT

Net electrical output	9 MW
Steam parameters	1250 psia, 910°F/180 psia
Annual wood-chips consumption	143,640 ODT
Annual heat output (net)	1,327 x 10^9 BTU
Thermal efficiency (average)	63.36%
Capital Cost	$16,400,000
Annual operating cost	$5,882,000
Cost of process heat	$4.89 per 10^6 BTU
Cost of by-procduct electricity	2.73¢ per kWh

SCHEME III - 60 TPD METHANOL PLANT

Methanol produced in a year	19,800 tons
Wood-chips required in a year	45,540 tons
Oxygen required in a year	7,590 tons
Electricity required in a year	7,922 MWh
Cold product efficiency	54.2%
Capital cost	$36,000,000
Annual operating cost	$3,953,400
Cost of methanol	40¢ per liter

TABLE 7.1

COMPARISON OF ELECTRICITY COSTS IN EASTERN ONTARIO, 1981

Source	
Electricity from:	
Ontario Hydro charges to muncipalities	2.86¢/kWh
Municipalities charges to industrial users	3.11¢/kWh
Wood-burning 9-MW cogeneration plant	2.73¢/kWh

Source: Ontario Hydro, Statistical Year Book, 1980 and forecasts provided by Ontario Hydro.

7.0 Comparison of Energy Costs

Electrical Power

In this section, we compare the costs of producing electrical power from the two wood-burning plants studied with the projected costs for power generated from Ontario Hydro.

Table 7.1, opposite, compares the cost of producing electrical power in 1981 dollars from a 9 MW cogeneration plant with the price of conventionally-produced electric power in Ontario. Electricity from the 9 MW station is competitive with rates charged by Ontario Hydro and the local municipalities in the region of Eastern Ontario.

Methanol and Gasoline

Table 7.2 compares the price of wood-derived methanol from a 60 TPD plant with the price of gasoline in 1981. The estimates for methanol have been adjusted for the lower BTU content and the higher end-use efficiency when burned as straight methanol in specially designed engines. While methanol derived from wood is not competitive with oil sold at the domestic price in 1981, it is cheaper than oil priced at the international level. Moreover, the projected domestic price of oil (based on the National Energy Program) in 1985 is expected to cost $18.80 per MM BTU's in 1981 dollars, indicating that the gap between wood-based methanol and conventional gasoline is expected to close over time as the Canadian price of oil approaches the world price.

TABLE 7.2

COMPARISON OF METHANOL AND GASOLINE PRICES, 1981

Fuel	Estimated Cost per MM BTU's in 1981 $
Methanol[1] from:	
Natural Gas	$19.00
Wood from Eastern Ontario	$23.60
Gasoline[2] based on the:	
Domestic crude oil price	$11.00
Average price of crude imported	$30.00
Projected domestic price of oil in 1985	$18.80

(1) Assumes:
- BTU content equals 16,938 per litre;
- methanol used as a straight (unblended) transportation which require a special engine;
- straight methanol burns 30% more efficiently than gasoline.

(2) Assumes:
- BTU content equals 32,819 per litre;
- no allownace for special taxes, such as the Canadian Ownership Tax;
- no increase in real price of refining and distributing gasoline.

Source: Ontario Ministry of Energy, "Alternative Transportation Fuels for Ontario: A Policy and Stragey". February, 1981.

8.0 Conclusions

The following conclusions flow from our preliminary analysis of the economics of wood conversion in Eastern Ontario.

1. The development of a 9 MW cogeneration facility is economically viable. Provided site conditions are suitable, this project provides an excellent example to demonstrate the opportunities for energy production from wood in the region of Eastern Ontario.

2. Although the economics of producing methanol are not favourable at this time, it is important to bear in mind that the project is primarily under investigation as a demonstration unit. In this regard, the project does hold some promise, in view of the fact that the production costs are not exceedingly high compared to the anticipated price of gasoline over the next two decades. Moreover, the unpredictability associated with future gasoline prices enhances the potential for methanol derived from wood.

   The size of plant necessary to yield acceptable economic results is believed to be in the upper region of 600 to 2400 tons per day. Given this fact, the economics of a larger plant should be investigated. This further study should be considered, especially in view of the fact that there is more than ample supplies of wood in the region to support a plant several times the size investigated in this report.

3. Further consideration and analysis should be given to the development of an energy complex involving a 9 MW cogeneration plant and a methanol plant. The advantages of this complex are:

   - a reduction in the requirements and costs of handling facilities for wood;

- electricity from the cogeneration plant could be sold to the methanol plant and to a suitable industrial user;

- steam from the cogeneration plant could be sold to an industrial user and to the methanol plant for drying of wood.

REFERENCES

1. Acres Shawinigan Ltd., Hearst Wood Waste Energy Study, Summary Report (January, 1979).

2. Wood Production and Conversion in Eastern Ontario: Phase 1, Wood Supply, Conversion Technology and Markets, report prepared for the Ontario Ministry of Energy by Peat, Marwick and Partners, (May, 1981), p.35.

3. Inter Group Consulting Economists Ltd., Economic Pre-Feasibility Study: Large Scale Methanol Fuel Production from Surplus Canadian Forest Biomass, Fisheries and Environment Canada, (Ottawa, 1976) Vol.2 and Report of Advisory Group on Synthetic Liquid Fuels of the Ministry of Energy (Toronto, 1978).

4. A survey of Canada's wood processing industry indicates that 47% of the bark produced in Canada is being put to use (mainly as fuel), while the remainder is being disposed of by incineration or landfill. The pulp and paper industry, which produced 38 % of the bark, used over 65% of its production for fuel, while the other processing industries, which produced 62% of the bark, used slightly less than 35% of their production for fuel. See R.D. Neill, "Options for the Use and Disposal of Bark" Pulp and Paper Canada (March 1976), pages 45-49.

5. There are many variations to the basic harvesting system discussed above. Possible variations include:
   - manual bucked logging system, using a forwarder with a self-loading hydraulic grapple, rather than a skidder.
   - manual felling, with processing by a mechanical limber-bucker and transport to landings by forwarder.
   - combination harvester for mechanical felling, bucking and limbing, together with a forwarder for transport to landings.

   In all the above cases, however, slash is left in the woods.

6. Pulp and Paper Research Institute of Canada, Production of Chemical Feedstocks from Wood Wastes, Volume I, Page IV-12 (1975).

7. J.P.R. Associates The Feasibility of Generating Electricity in the State of Vermont Using Wood as a Fuel (Stowe, Vermont: 1975).

8. Sections 4 and 5 draw on analysis conducted in the Acres Shawinigan, Hearst Wood Waste Energy Study prepared for The Ontario Government, Town of Hearst and Hearst Lumberman's Association, (Toronto, 1979). (see reference 1.)

9. Ontario Ministry of Energy, Alternative Transportation Fuels for Ontario: A Policy and Strategy, February, 1981.

APPENDIX A

FORECASTS OF SELECTED ENERGY PRICES

APPENDIX A

MINISTRY OF ENERGY
FORECASTS OF SELECTED ENERGY PRICES(1)
1981-2000
(February, 1981)

	CRUDE OIL		NATURAL GAS		LIGHT FUEL		ELECTRICITY PRICES	
	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
	($/barrel)		($/mcf)		(¢/litre)		(¢/kwh)	
1981	24.40	24.40	4.40	4.42	23.3	23.3	3.12	3.12
1985	41.75	46.67	6.84	7.61	36.1	40.2	4.60	4.60
1990	72.57	78.91	12.02	13.32	58.5	64.8	6.45	6.76
1995	118.01	124.48	18.73	20.43	91.0	99.3	9.05	9.93
2000	174.30	190.84	27.02	30.69	131.8	149.5	12.69	14.60

(1) Landed refiner's price; all other fuels priced as Toronto residential.

Major Assumptions: Low Oil Price Scenario

1. World price of oil rises to $50 U.S. (1980 $) by 2000.

2. Natural gas prices (Toronto city-gate):
   - 69% in 1984
   - 72% in 1985
   - 75% in 1986
   - 78% in 1987
   - 80% in 1988 in a BTU equivalent to oil.

3. Inflation rate:
   - 9.2% p.a. for 1981-85
   - 8% p.a. for 1985-2000.

Major Assumptions: High Oil Price Assumption

1. World price of oil increases to $60 U.S. (1980 $) by 2000.

APPENDIX B

COMPARISON OF WOOD FUEL DEMAND FORECASTS

APPENDIX B

COMPARISON OF WOOD FUEL DEMAND FORECASTS

An area of considerable interest is the current and future demand for wood fuel in Eastern Ontario. As indicated in the body of this report, the quality of data on fuel wood markets is relatively poor and thereby requiring researchers to undertake basic assumptions regarding consumer price sensitivity and consumer preferences in general. The Ontario Ministry of Natural Resources, at the time of writing, is undertaking a major household survey of wood fuel consumption. Until this survey is completed, we have had to rely on other published reports and our own analysis.

This appendix presents forecasts prepared by Peat, Marwick and Partners (PMP) with forecast prepared by J. Balatineca and W. Clark (B&C) for the Ontario Ministry of Treasury and Economics (October 1978). Each forecast includes the major assumptions used so that the reader can compare the basis for each projection.

WOOD FUEL DEMAND ESTIMATES

	ODT/Yr.	
	PMP (1980)	B&C (1978)
Space Heating	143,000	165,750
Cooking and Water Heating	52,000	-
Auxillary Heating	119,250	47,970
Recreational Demand	16,000	45,240
	330,250	258,960

WOOD FUEL DEMAND FORECASTS, 1990

	ODT/Yr.	
	PMP	B&C
Space Heating	183,000	N.P
Cooking and Water Heating	52,000	N.P
Auxillary Heating	153,000	N.P
Recreational	16,000	N.P
	404,000	520,000

N.P. Not Provided

PMP MAJOR ASSUMPTIONS

- Total of 160,000 dwellings in region.
- No change in the number of dwellings using wood as primary fuel from the 1971 census, rather than a continuation of the downward trend that had existed from 1951 to 1971.
- A total of 8,000 dwellings using wood for space heating purposes at an average annual demand of 17.9 ODT's per dwelling.
- 53,000 dwellings (33% of region) using wood as an auxillary fuel in fireplaces or stoves with an average annual demand of 2.25 ODT.

B&C MAJOR ASSUMPTIONS

- Total of 238,810 dwellings in the region.
- Total of 7,800 dwellings heating with wood fuel at an average annual demand of 21.25 ODT's.
- 67,990 dwellings using fireplaces with an average annual demand of .70 ODT.

* Cords have been converted to ODT's using a factor of 1.3.

APPENDIX C

ESTIMATES OF ENERGY EFFICIENCIES

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STANDARD RESIDENTIAL USE

Oil	60 - 70%
Natural Gas	65 - 70%
Electricity	100%

Wood burning:

Fireplace	10%
High efficiency air tight stove	60 - 70%
Typical Franklin Stove	30 - 40%

Source: D. Andrews and P. Bakker, Ontario Ministry of Energy, July, 1981